

Accepted Manuscript

From Human to Artificial Cognition and Back: New Perspectives on Cognitively Inspired AI Systems

Antonio Lieto, Daniele P. Radicioni

PII: S1389-0417(16)30018-3

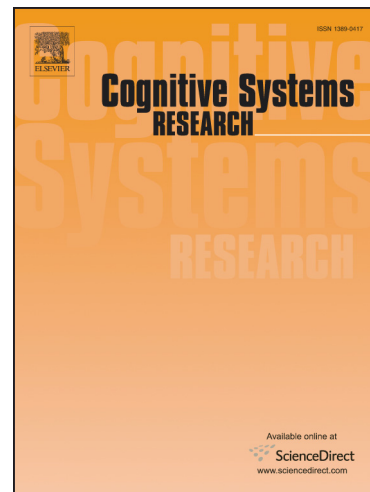
DOI: <http://dx.doi.org/10.1016/j.cogsys.2016.02.002>

Reference: COGSYS 488

To appear in: *Cognitive Systems Research*

Received Date: 3 February 2016

Accepted Date: 3 February 2016



Please cite this article as: Lieto, A., Radicioni, D.P., From Human to Artificial Cognition and Back: New Perspectives on Cognitively Inspired AI Systems, *Cognitive Systems Research* (2016), doi: <http://dx.doi.org/10.1016/j.cogsys.2016.02.002>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

From Human to Artificial Cognition and Back: New Perspectives on Cognitively Inspired AI Systems

Antonio Lieto^{a,b}, Daniele P. Radicioni^a

^a*University of Turin, Dip. di Informatica, Corso Svizzera 185, Torino, Italy*

^b*ICAR-CNR, edificio 11, Viale delle Scienze, Palermo, Italy*

Abstract

We overview the main historical and technological elements characterising the rise, the fall and the recent renaissance of the cognitive approaches to Artificial Intelligence and provide some insights and suggestions about the future directions and challenges that, in our opinion, this discipline needs to face in the next years.

Keywords: Cognitive Systems, Artificial Intelligence, Computational Models of Cognition, Epistemology of the Artificial.

The scientific vision of the early Artificial Intelligence (AI) can be successfully synthesized by the words of Pat Langley: “AI aimed at understanding and reproducing in computational systems the full range of intelligent behaviour observed by humans” (Langley, 2012). This approach, known as the ‘cognitivist’ approach to AI according to the terminological distinction provided by Vernon (Vernon, 2014), borrowed its original inspiration –from a historical perspective– from the methodological approach developed by scholars in Cybernetics (Cordeschi, 1991). In this perspective, the computational simulation of biological processes was assumed to play a central *epistemological* role in the development and refinement of theories about the elements characterizing the nature of intelligent behaviour in natural and artificial systems. As a consequence, it was also crucial for the development of artificial solutions inspired by human processes and heuristics (Gigerenzer & Todd, 1999).

Likewise, thanks to the computational approach to Cognitive Science, in-

15 intelligent systems based on computational models and architectures of cognition
have been also proposed with the aim at providing a deeper understanding of
human thinking, as originally suggested in the manifesto of the *Information*
Processing Psychology (IPP) (Newell & Simon, 1972).

After the first decades of pioneering collaborations, however, starting from
20 the mid 80's of the last Century, Artificial Intelligence and Cognitive Science
have started to produce several sub-fields, each with its own goals, methods and
evaluation criteria. On the one hand this fragmentation led AI to reach remark-
able results in a variety of specific fields by focussing on quantitative results and
metrics of performance, and on a machine-oriented approach to the intelligent
25 behaviour (i.e., without taking into account human-inspired heuristics). On
the other hand, however, it has significantly inhibited the cross-field collabora-
tions and the research efforts targeted at investigating a more general picture
of what natural and artificial intelligence is, and how intelligent artifacts can
be designed by taking into account the insights coming from human cognition.
30 Nowadays, in fact, artificial systems endowed with human-like and human-level
intelligence (McCarthy, 2007) are still far from being achieved. Given this state
of affairs, in the last few years the cognitive approach to AI gained a renewed
consideration, both from academia and industry, in wide research areas such as
Knowledge Representation and Reasoning, Robotics, Machine Learning, Bio-
35 Inspired Cognitive Computing, Computational Creativity and further research
fields that aspire to Human Level Intelligence (also called AGI, Artificial General
Intelligence) in designing computational artifacts.

The AIC workshop series on Artificial Intelligence and Cognition¹ (most
works in the current Special Issue are selected and extended versions of the
40 papers presented therein), played, in this perspective, a recognized role of pro-
motion and development of this movement, at least in Europe (Lieto & Cruciani,
2013; Lieto et al., 2014; Lieto & Cruciani, 2015; Lieto & Radicioni, 2015).

This sort of 'cognitive renaissance' of AI, essentially, still considers the "cog-

¹ <http://dblp.uni-trier.de/db/conf/aic/>

nition in the loop” approach as a useful one to detect and unveil novel and
 45 hidden aspects of the cognitive theories by building properly designed compu-
 tational models of cognition useful to progress towards a deeper understanding
 of the foundational roots of intelligence (both in natural and artificial systems).
 An important methodological aspect to consider within this framework regards
 the explanatory role played by such artificial models (and systems) with respect
 50 to the target natural cognitive systems they take as source of inspiration. In
 particular, models and systems based on the methodological approach known
 as *functionalism*² and, therefore, purely based on a weak equivalence (i.e. the
 equivalence in terms of functional organization) between cognitive processes and
 AI procedures are not good candidates for providing advances in the science of
 55 cognitive AI (and this is the case, for example, of technologies like IBM Wat-
 son. In this case, in fact, the adoption of the expression “cognitive system”
 represents a misuse). On the other hand, since it is currently not possible to
 reproduce a realistic strong equivalence between a computational model/system
 and a target natural system (such as human cognition),³ the only way to make
 60 progress is based on the development of plausible structural models of our cog-
 nition based on a more constrained equivalence between AI procedures and their
 corresponding cognitive processes. Only models and systems based on the de-
 sign constraints proposed by the “structural” approach⁴ can be considered good

²Functionalism was introduced in the philosophy of mind by Putnam in his seminal article
 entitled *Minds and Machines* (Putnam, 1960). In its more radical formulation it postulates
 the sufficiency, from an epistemological perspective, of a weak equivalence between cognitive
 processes and AI procedures and propose that, from an explanatory point of view, the rela-
 tion between “natural mind” and “artificial software” can be based purely on a macroscopic
 equivalence of the functional organization of the two systems. This position has been widely
 criticized in the literature in the last decades (also by Putnam himself).

³This phenomenon is known as the “Wiener paradox”, and can be summarized through
 Wiener’s own words about the fact that “the best material model of a cat is another or possibly
 the same cat” (Rosenblueth & Wiener, 1945). In short, this “paradox” advocates for the need
 of the realization of proxy-models, not *replicas*, of a given natural system by pointing out the
 difficulty of such challenge.

⁴Differently from the *functionalism*, the structural approach claims for the epistemological

“proxies” of a the target cognitive system taken as inspiration, and can play
 65 an explanatory role about it (Cordeschi, 2002; Miłkowski, 2013).

According to such approach, these kinds of models and systems can be useful
 both to advance the science of AI in terms of technological achievements (e.g.
 in tasks that are easily solvable for humans but very hard to solve for machines,
 such as - for example - in common sense reasoning) and to play the role of “com-
 70 putational experiments”, able to provide insights and results useful in refining
 or rethinking theoretical aspects concerning the target biological system used
 as source of inspiration. This perspective –along with the many challenges it
 forces us to accept– represents the pillar of this Special Issue and, at different
 levels of granularity, the papers selected in this issue illustrate systems that can
 75 be ascribed to this approach of cognitive AI.

Under a historical perspective, this Special Issue also appears in a very
 important occasion since in 2016 falls the 60th anniversary of the Dartmouth
 Conference, the event which actually inaugurated the history of Artificial Intelli-
 gence (AI) and Cognitive Systems research. As mentioned, many of the pioneers
 80 who settled AI as a research discipline shared the dream of (re-)creating high-
 level intelligence through computational means, i.e., achieving human-level AI
 by taking inspiration from the heuristics of the human cognition. This goal is
 still being pursued (although with varied interpretations) by many researchers
 all around the world, and it still represents one of the main challenges for the
 85 AIC community.

In the following we provide a quick tour on the works appearing in the Spe-
 cial Issue. The article *What is ‘Wrong’ in a Neural Model* by Alessio Plebe
 presents a biologically plausible neurocomputational model of moral behaviour;
 such a model is implemented in a neural network that combines reinforcement
 90 and Hebbian learning. The model is used to simulate the interaction of the sen-
 sorial system with emotional and decision making systems in situations involving

need of artificial models whose “functions” are designed and implemented by considering the
 same “structures” (i.e. the same biological and cognitive “constraints”) of human cognition.

moral judgments. The article *Object Replacement and Object Composition in a Creative Cognitive System. Towards a Computational Solver of the Alternative Uses Test* by Ana-Maria Olteteanu & Zoe Falomir proposes a creative
 95 approach to problem solving defined through a cognitive architecture where a goal can be reached by replacing a missing object with another one with similar affordance; alternatively, a suitable object can be composed with other ones that are present in the environment. The work *Hierarchies of Self-Organizing Maps for Action Recognition* by Haris Dindo, Miriam Buonamente and Magnus
 100 Johnsson presents a hierarchical neural architecture, based on Self-Organizing Maps (SOMs), designed to recognize observed human actions. The article *Image Schemas in Computational Conceptual Blending* by Maria M. Hedblom, Oliver Kutz and Fabian Neuhaus is an investigation on the role of image schemas in the concept creation process; it also shows how this approach has led to the de-
 105 velopment of a library of formalized image schemas that provide heuristics for the computational blending of concepts. The work *Multilayer Cognitive Architecture for UAV Control* by Stanislav Emel'yanov, Dmitry Makarov, Aleksandr I. Panov and Konstantin Yakovlev presents an architecture designed for dealing with control problems in the field of unmanned aerial vehicles. The proposed
 110 architecture includes a three-layered structure, including a strategic level (accounting for high-level cognitive tasks, such as planning, prioritizing tasks), a tactical level (concerned with navigation activities) and a reactive level (intended to generate various sorts of control signals).

We are indebted to the referees of this special issue that helped us in the
 115 selection process. We thank: Agnese Augello, Cristina Bosco, Eduardo Datteri, Marcello Frixione, Anna Jordanous, Othalia Larue, Alessandro Oltramari, Viviana Patti, Alessio Plebe, Viola Schiaffonati, Sara Tonelli and Fabio Massimo Zanzotto.

1. References

- 120 Cordeschi, R. (1991). The discovery of the artificial. some protocybernetic developments 1930–1940. *AI & society*, 5, 218–238.
- Cordeschi, R. (2002). *The discovery of the artificial: Behavior, mind and machines before and beyond cybernetics* volume 28. Springer Science & Business Media.
- 125 Gigerenzer, G., & Todd, P. M. (1999). *Simple heuristics that make us smart*. Oxford University Press, USA.
- Langley, P. (2012). The cognitive systems paradigm. *Advances in Cognitive Systems*, 1, 3–13.
- Lieto, A., & Cruciani, M. (2013). Artificial intelligence and cognition. *CEUR-ws* 130 volume 1100.
- Lieto, A., & Cruciani, M. (2015). Introduction to cognitive artificial systems. *Connection Science*, 27, 103–104.
- Lieto, A., & Radicioni, D. P. (2015). Advances in artificial intelligence and cognition. *Proceedings of EAP-COGSCI 2015 Conference, Euro-Asian Pacific* 135 *Joint Conference on Cognitive Science*, (pp. 25–26).
- Lieto, A., Radicioni, D. P., & Cruciani, M. (2014). International workshop on artificial intelligence and cognition. *CEUR-ws*, 1315.
- McCarthy, J. (2007). From here to human-level ai. *Artificial Intelligence*, 171, 1174–1182.
- 140 Miłkowski, M. (2013). *Explaining the computational mind*. Mit Press.
- Newell, A., & Simon, H. A. (1972). *Human problem solving* volume 104. Prentice-Hall Englewood Cliffs, NJ.
- Putnam, H. (1960). *Minds and machines*. MacMillan.

Rosenblueth, A., & Wiener, N. (1945). The role of models in science. *Philosophy*
145 *of science*, 12, 316–321.

Vernon, D. (2014). *Artificial cognitive systems: A primer*. MIT Press.